



Fatigue Damage Analysis of an Elastomeric Tank Track Component

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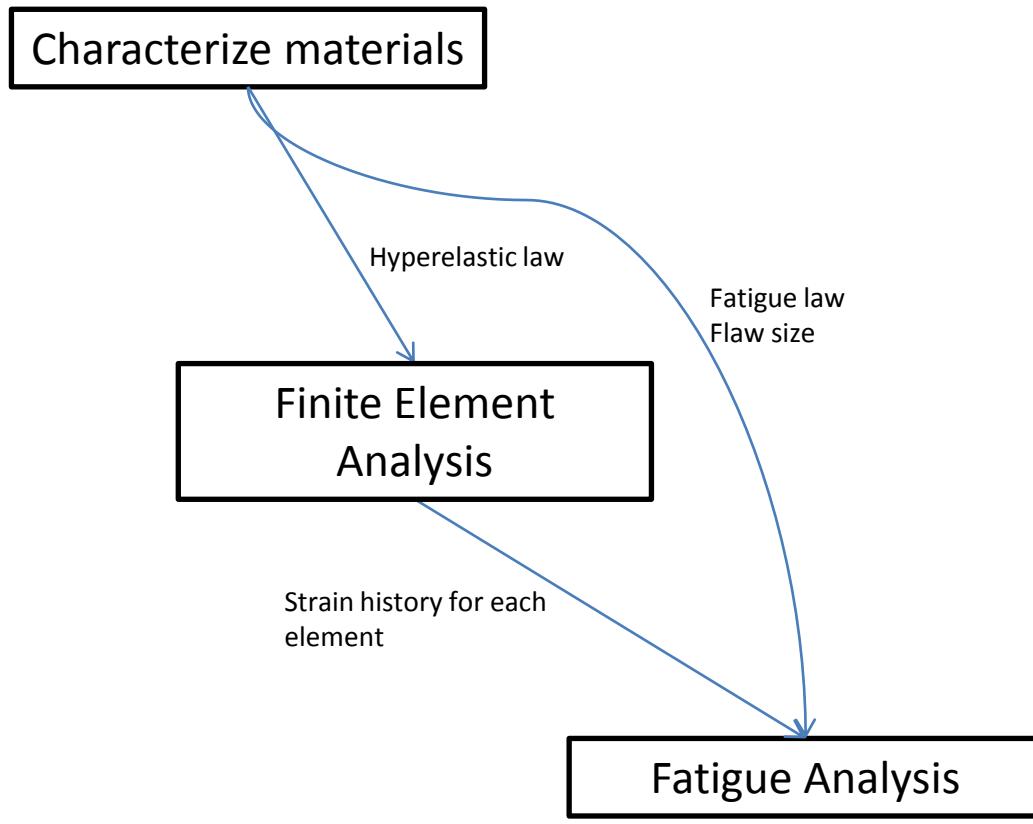
M1 Abrams Tank



Purpose

- Demonstrate simulation-based design qualification capability for fatigue of elastomers
- Application to an elastomeric backerpad operating as a part of the M1 Abrams track system
- Estimate failure location and crack nucleation life
 - Elastomeric material behavior
 - Realistic duty cycle

Plan



Powered by Endurica

Fatigue Analysis Strategy

$$T = g(\varepsilon_{ij}, \theta, \phi) a$$

ERR of a small probe crack scales linearly with crack size, and depends on strain state and crack orientation

$$\frac{da}{dN} = f(T_{\max}, R)$$

Crack growth rate for an individual event-pair

$$r = \sum_{i=1}^M f_i(T_{\max}, R)$$

Crack growth rate per application of given duty cycle

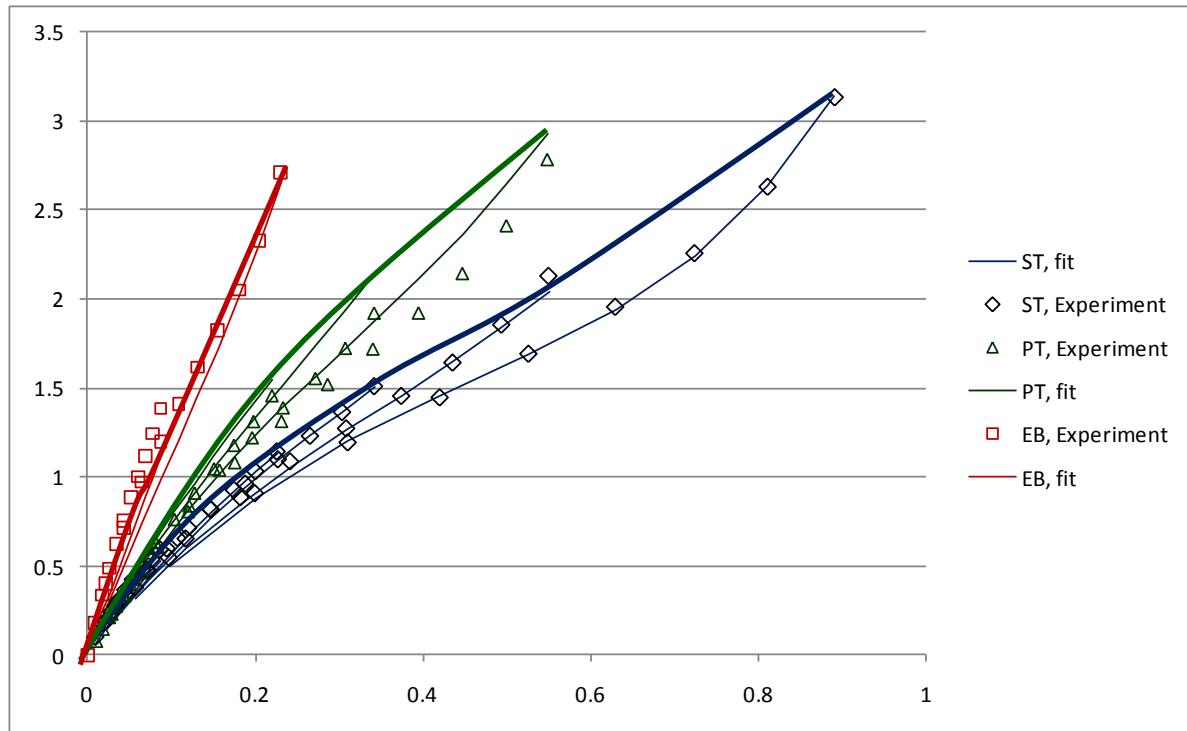
$$N_{\theta,\phi} = \int_{a_0}^{a_f} \frac{1}{r(T(a,t))} da$$

Number of repeats of duty cycle required to develop a crack

$$N_f = \min_{\theta,\phi}(N_{\theta,\phi})$$

Life minimization to identify critical plane

Stress-Strain Behavior



```

MU1=2.275319 ! MPa
MU2=0.054452 ! MPa
ALPHA1=-1.00837
ALPHA2=7.863497
MULLINNSR=6.641545796
MULLINSM=0.558478587 ! MPa
MULLINSBETA=0.029639767
BULK_MODULUS=140.7 ! MPa

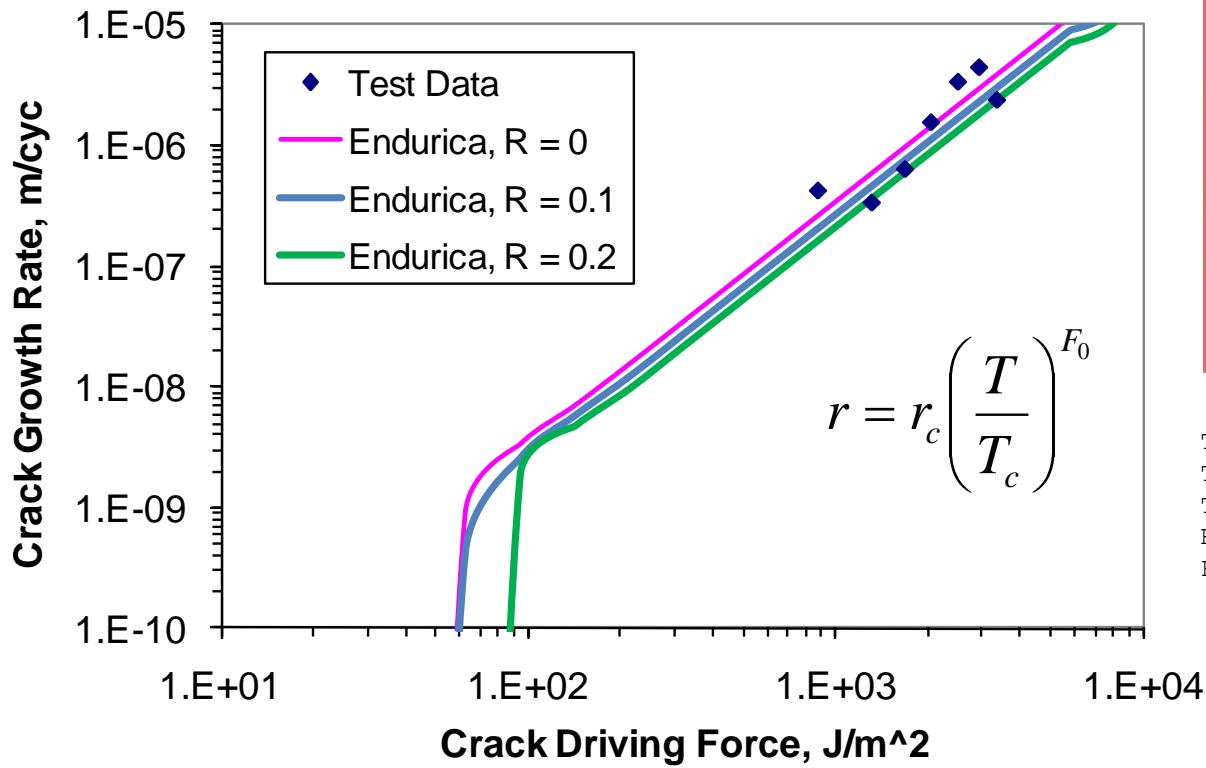
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$$W = \sum_{i=1}^N \frac{2\mu_i}{\alpha_i^2} \left(\bar{\lambda}_1^{\alpha_i} + \bar{\lambda}_2^{\alpha_i} + \bar{\lambda}_3^{\alpha_i} - 3 \right)$$

$$W = \eta \tilde{W}(I_1, I_2) + \phi(\eta)$$

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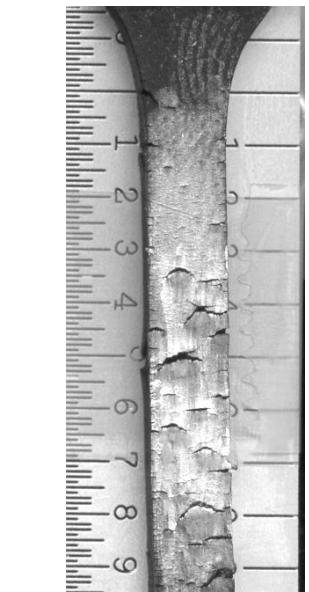
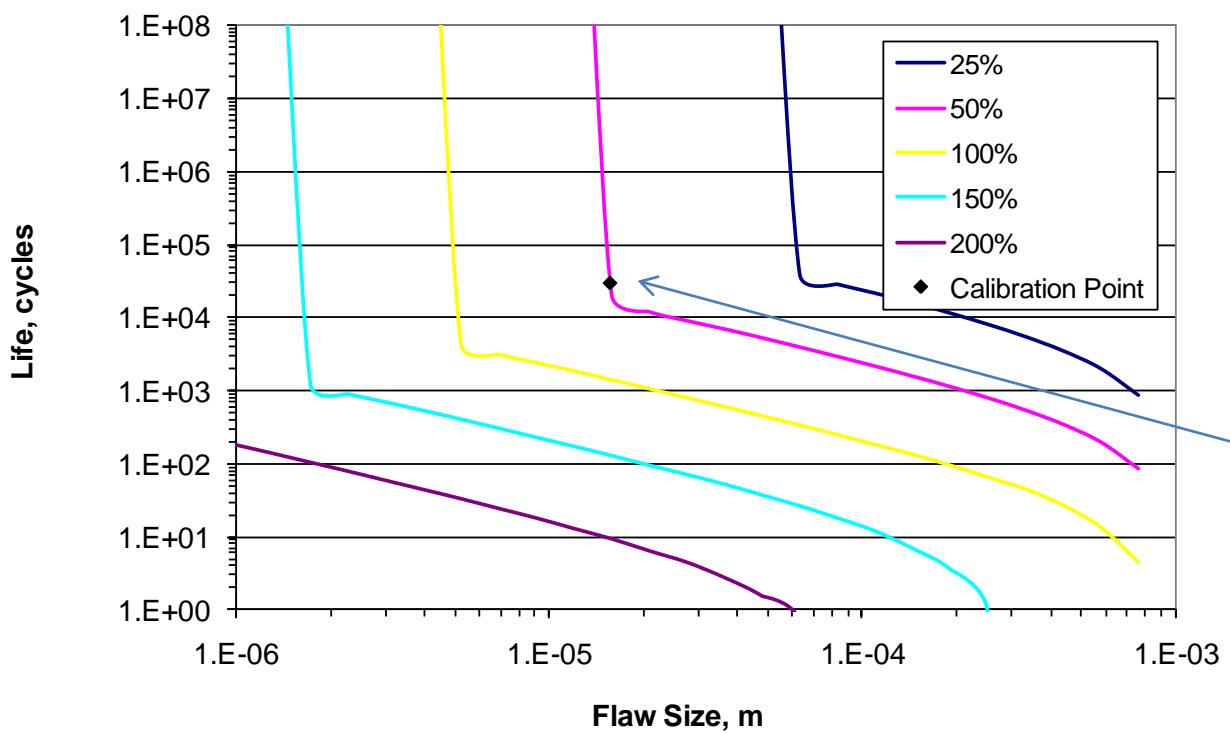
Fatigue Crack Growth Law



TCRITICAL=10e3 ! J/m^2
THRESHOLD=50 ! J/m^2
TRANSITION=150 ! J/m^2
RC=3.42E-5 ! m/cyc
F0=2

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Material Microstructural Feature Size



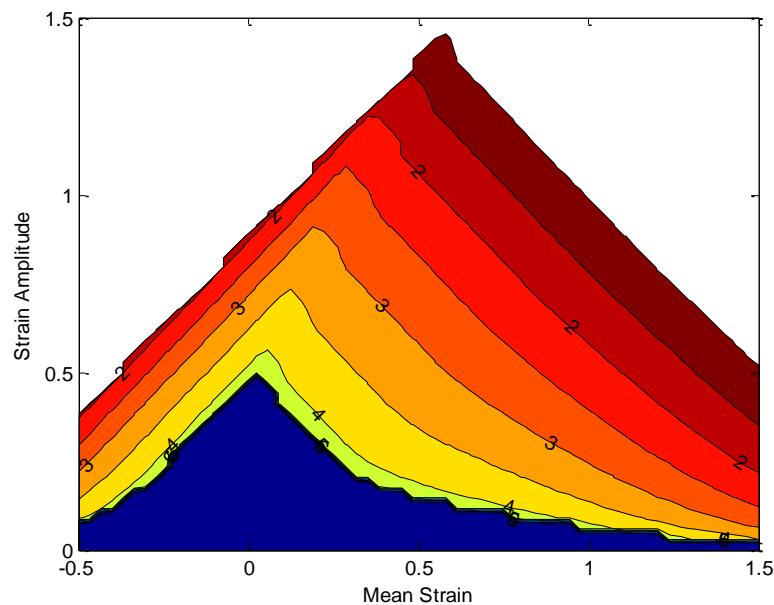
Simple Tension

$$N_{\theta,\phi} = \int_{a_0}^{a_f} \frac{1}{r(T(a,t))} da$$

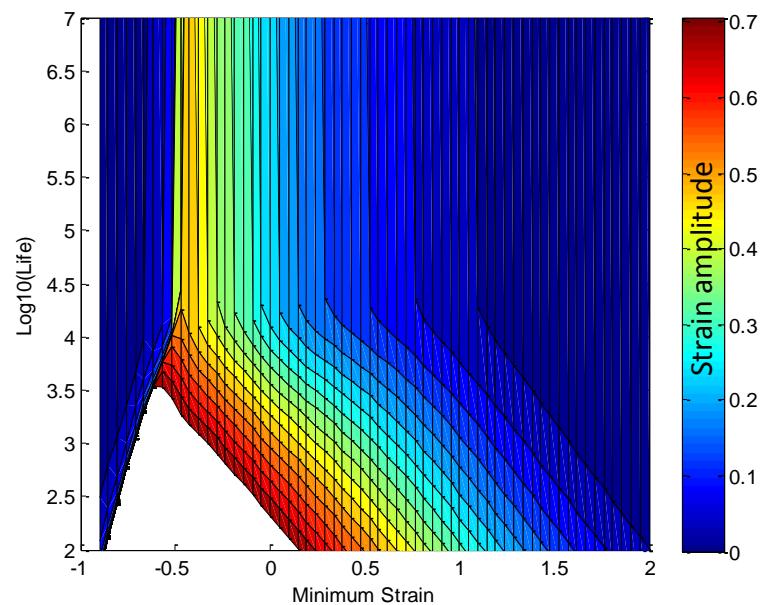
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Computed Fatigue “Design Envelopes”

Haigh Diagram

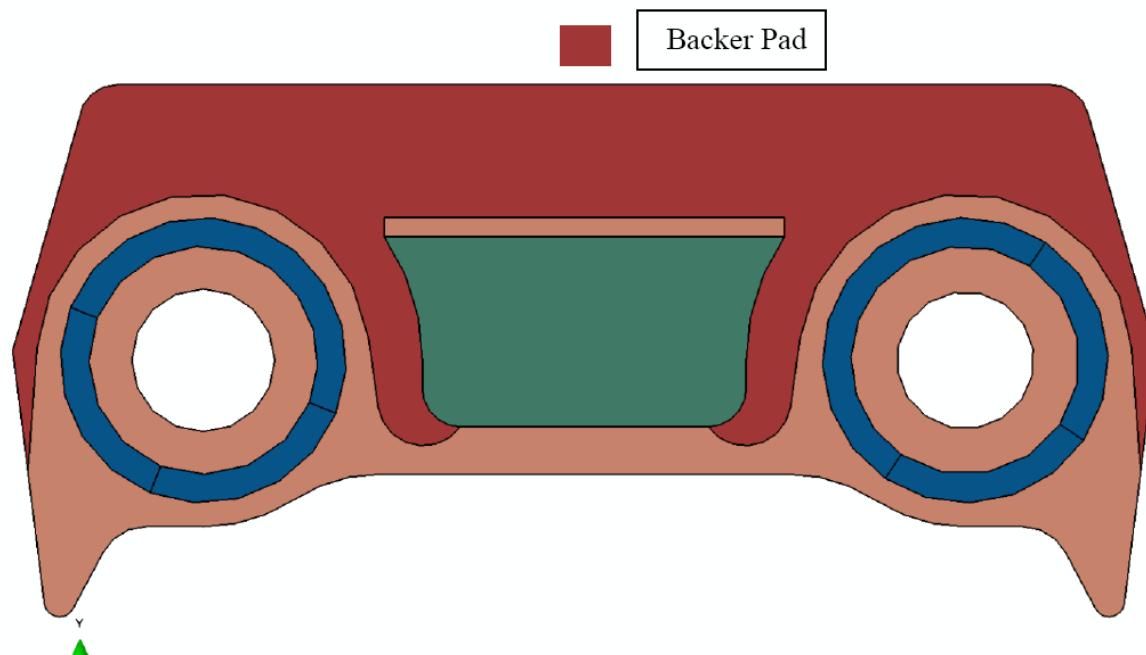


Cadwell Diagram



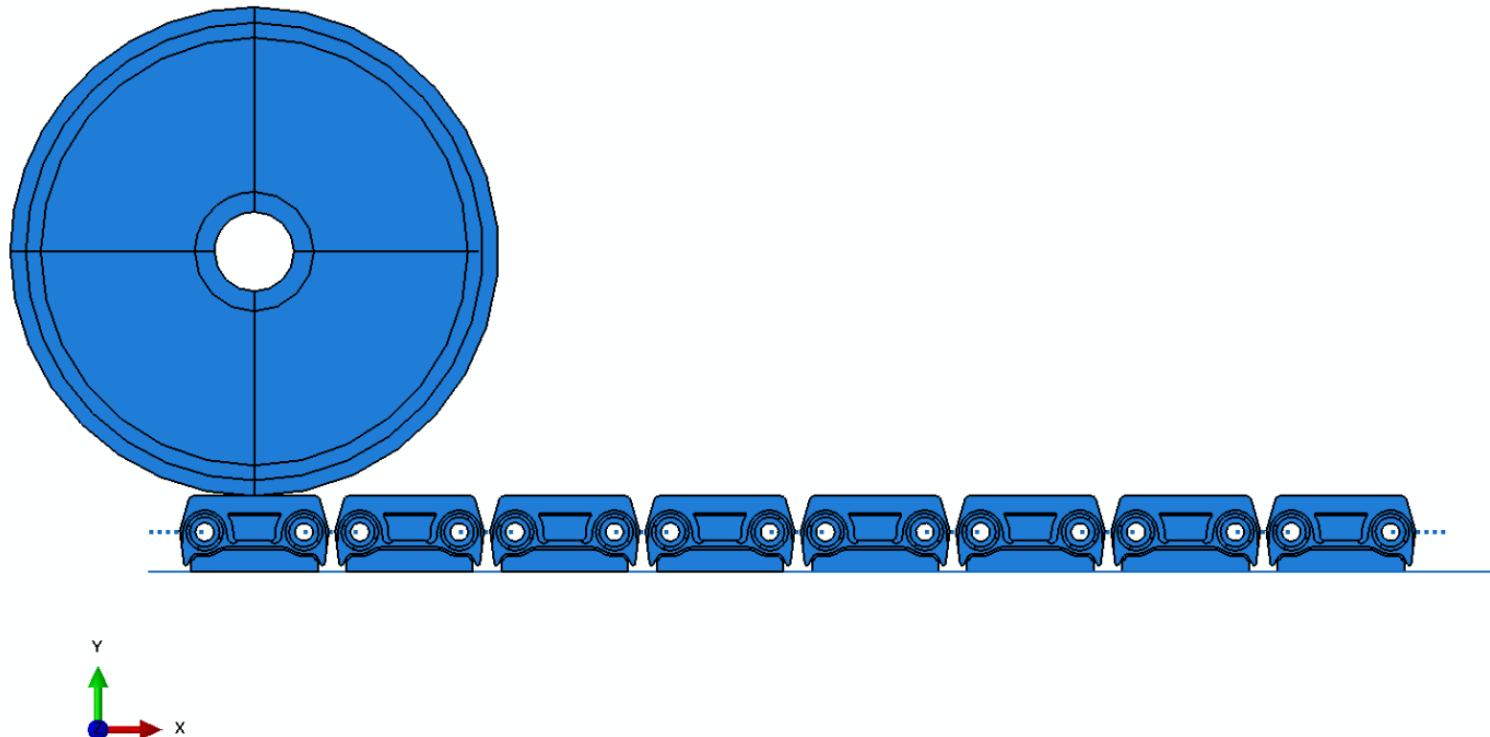
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Backerpad Geometry



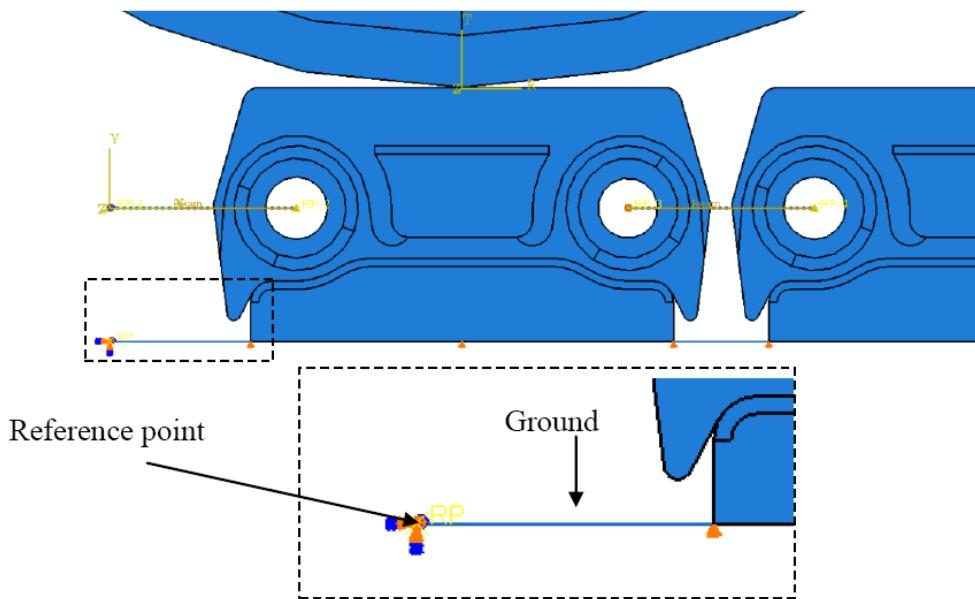
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Operating Scenario



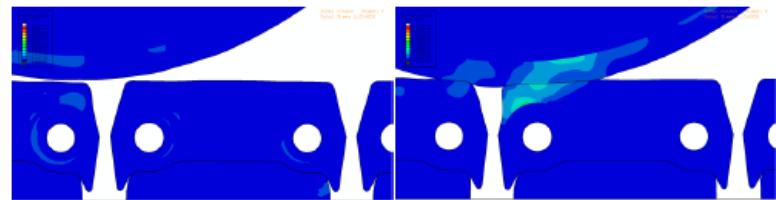
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Boundary Conditions - Detail



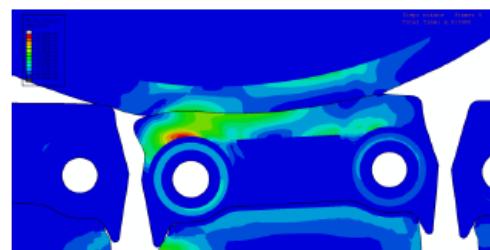
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Typical rollover event highlights

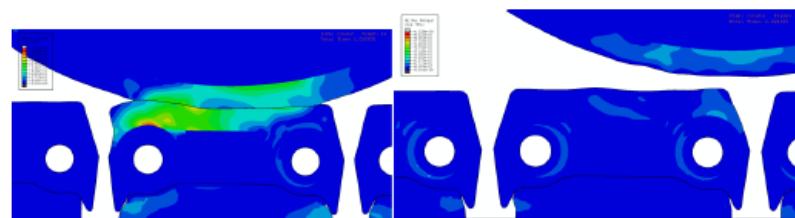


$t = 2.014$

$t = 2.016$



$t = 2.018$



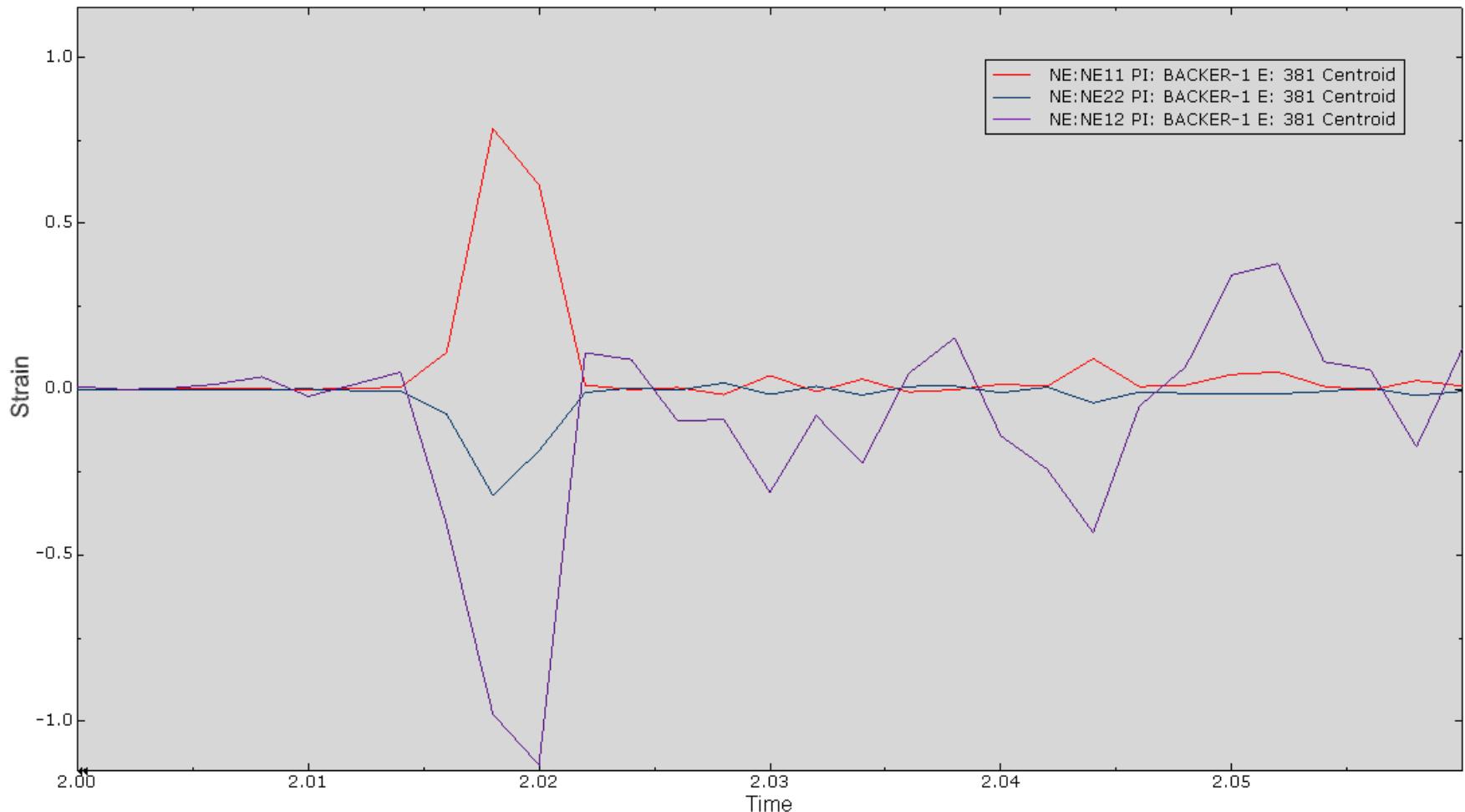
$t = 2.020$

$t = 2.022$

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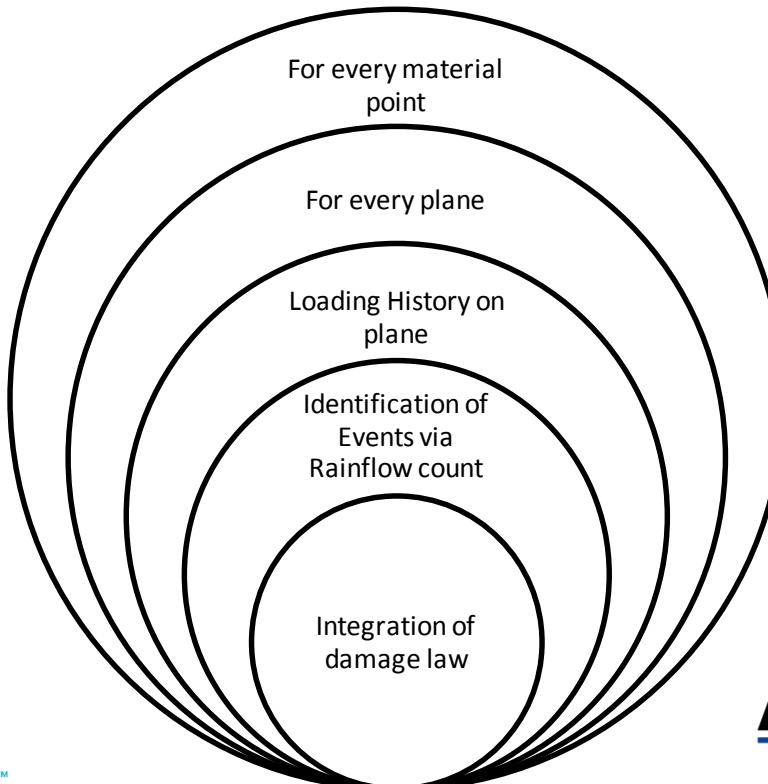
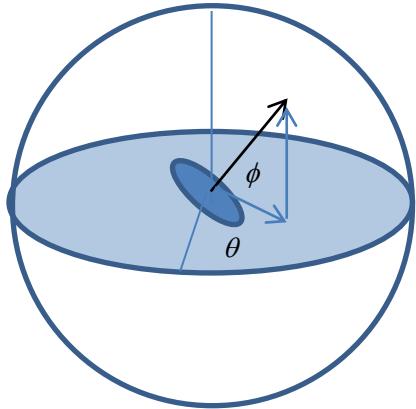
Contours of max prin strain

Strain history at typical location

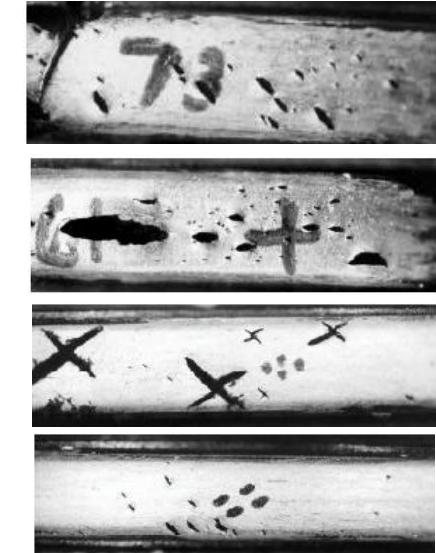


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Critical Plane Analysis



Identification of material
point and plane with
minimum life



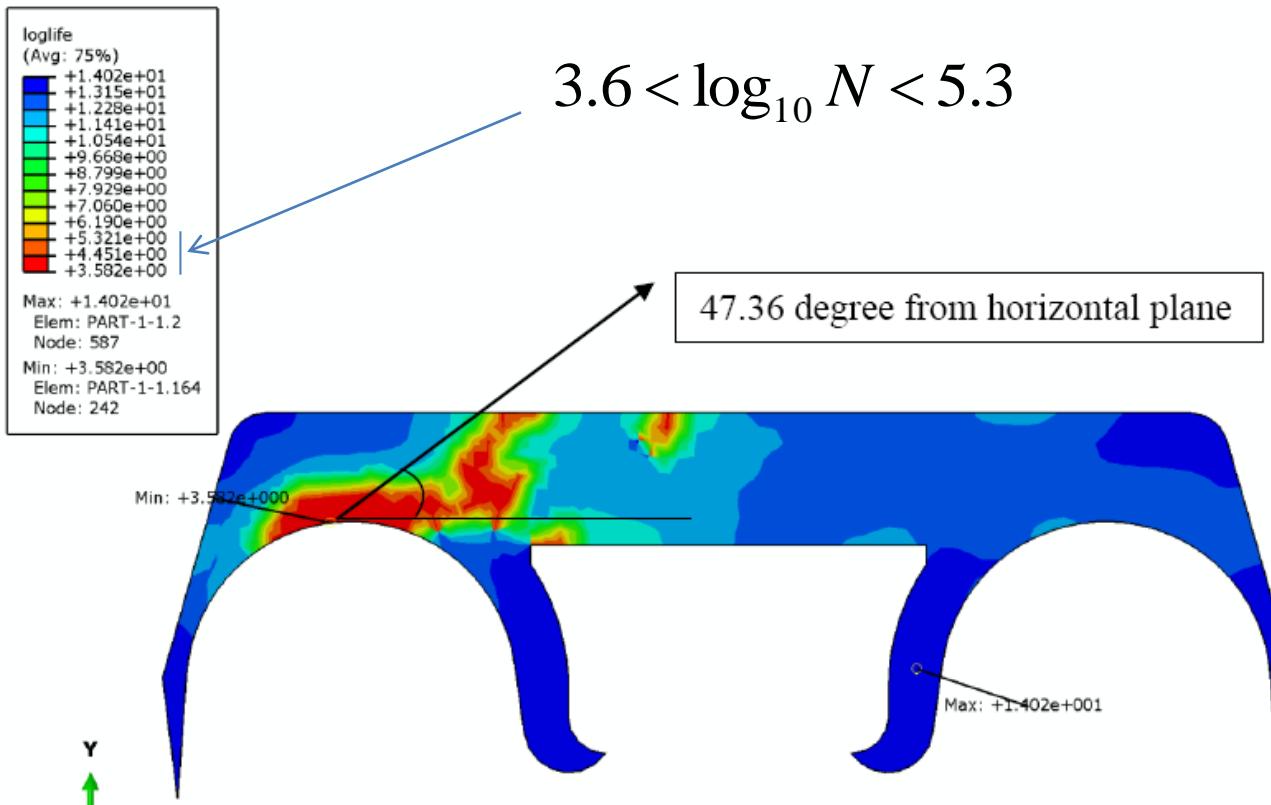
EnduricaTM
Accelerating Reliable Design

 fe-safe/Rubber™

US PATENT NO. 6,634,236 B1

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Results



Typical damage development



New

500 miles

1000 miles

$$\log_{10} \left(90 \frac{revs}{mile} \times 500 \text{ mile} \times 7 \frac{\text{cycles}}{rev} \times \frac{1}{3} \frac{mm}{mm} \right) = 5.02$$

Conclusion

- Introduced a simulation-based approach for estimating elastomer fatigue crack nucleation life under complex dynamic loads
- Demonstrated
 - characterizing rubber's fatigue behavior via fracture mechanics procedures
 - computing damage accumulation under complex service conditions using a critical plane analysis strategy
 - encouraging comparison to reality

Outlook

- Army funded SBIR Phase II project to expand features, validation, and application of the code.
- Partnership with Axel Products now offers Fatigue Design Envelope characterization service.
- Partnership with Safe Technology offers post-processing solution Fe-safe/Rubber (coming soon).

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Abstract

- *Abstract: The backerpad on the Abrams tank track system is an elastomeric cushion that protects the track and has direct contact with the tank's wheels. The backerpad's service life is limited by harsh operating conditions, and system designers are challenged to extend that limit. Accordingly, an analysis is demonstrated here of an experimental backerpad's fatigue performance under the action of a tank roadwheel repeatedly rolling over the pad. First, the elastomer is characterized via tests that define its fatigue behavior. Next, the multiaxial, variable amplitude duty cycle of the pad through a representative rollover event is computed in ABAQUS/Explicit. Finally, the material characterization and duty cycle are analyzed via the fe-safe/Rubber fatigue life solver to estimate damage accumulation in each finite element of the model. The calculation identifies the location and number of duty cycle repeats associated with the first appearance of 1 mm cracks for the selected duty cycle, providing an example of how fatigue analysis may be applied to understand damage development in elastomeric components.*
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- *Keywords: Damage, Fatigue, Elastomer, Material Characterization, Postprocessing*